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**A DESIGN FOR AN EXPERIMENT TO MONITOR
THE PHYSICAL FATE OF OIL SPILLED IN AN
OPEN OCEAN ENVIRONMENT**

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OIL SPILLED IN AN OPEN OCEAN ENVIRONMENT

by

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**A DESIGN FOR AN EXPERIMENT TO MONITOR THE
PHYSICAL FATE OF OIL SPILLED IN
AN OPEN OCEAN ENVIRONMENT**

A Report Prepared for

**The Environmental Emergency Branch
Environmental Protection Service
Environment Canada
Ottawa**

by

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1. INTRODUCTION

The occurrence of oil spills from shipping incidents and the threat of potential oil spills in the future from oil exploration and production has generated considerable research effort toward an understanding of the properties and fate of spilled oil. The physical properties of oil and the effects of dispersant application to oil has been studied at the laboratory and mesoscale levels to the point that the data at these levels is relatively complete. Some large scale experiments have been carried out, notably the Baffin Island Oil Spill (BIOS) Project and the East Coast Aerial Dispersant tests. These experiments had specific and quite narrow goals; carefully chosen for probable success. The next level of experimentation is the very large scale spill, where realistic conditions will apply. The justification for purposely spilling such a large amount of oil cannot be found. The only justifiable choice is to wait for a spill of opportunity.

One of the most significant results to come from all of the previous experiments and the work done in other countries on real and experimental spills is the direct correlation between planning and the generation of useful data. Some planning for a response to spills of opportunity has been done in the past in Canada. As part of the Beaufort Sea Study, a report was prepared describing desired scientific responses to accidental spills (Ward et al, 1977). Some parts of this report were subsequently used to develop the BIOS Project. In 1982, planning reports were prepared for the Atlantic (Keizer, 1982) and Pacific (Green et al, 1982) coasts. These reports collectively proposed thirty projects, including physical, chemical, and biological studies with a total estimated cost of \$0.9M. The terms of references for these reports did not restrict the cost of the proposed studies, but assumed that evaluation would occur later. This evaluation appeared in a report by Donald Mackay (1982), who used the three above mentioned reports and others to develop a list of priorities for experiments.

The present report describes a possible response to a spill of opportunity. The budget for such a study has been restricted to approximately \$50,000. This restriction narrows the potential areas of study, both scientifically and geographically.

In the past fifteen years, a number of models of oil spill behaviour have been developed and refined. The testing of these models has been limited to occasional

data from accidental spills and some data from experimental spills. A response plan which would increase the quantity and quality of the data obtained from accidental spills, data specifically aimed at the testing of some modelling predictions, would be very useful. This report provides such a plan.

1.1 General Considerations

A great many processes may take place during an oil spill. Figure 1 represents graphically the complexity of the behaviour of spilled oil. In order to have a reasonable chance of obtaining useful data, the processes examined must be chosen to fit the likely time scale available and require simple data acquisition techniques.

While shore stranding of oil and the effects of oil on biota, both on and offshore, are extremely important topics, they both require relatively long term studies and very complex sampling and analysis procedures to obtain statistically valid results.

The movement and behaviour of the spilled oil lends itself to study under the circumstances of a spill of opportunity. While the oil is on the sea surface and moving freely, considerable useful data may be obtained. Prediction of the movement and spreading of the slick is critical to most models. The two processes of evaporation and dispersion are considered to be the major pathways for the weathering of oil spilled at sea. A hypothetical time course for these two processes is depicted in Figure 2. The processes of spreading, evaporation and dispersion are interrelated and most likely to be studied successfully.

1.2 Data Requirements

Slick movement models require input of wind speed and direction and water currents. To test the model output, measurement of slick position is necessary.

Spreading models require, as input data, the viscosity, density and interfacial oil-air and oil-water tensions. These data may be measured in the laboratory if samples of freshly spilled or unspilled oil are taken. The models also require data on the atmospheric conditions and water temperature. To test the model output, measurements of slick area for both thick and thin slicks are necessary.

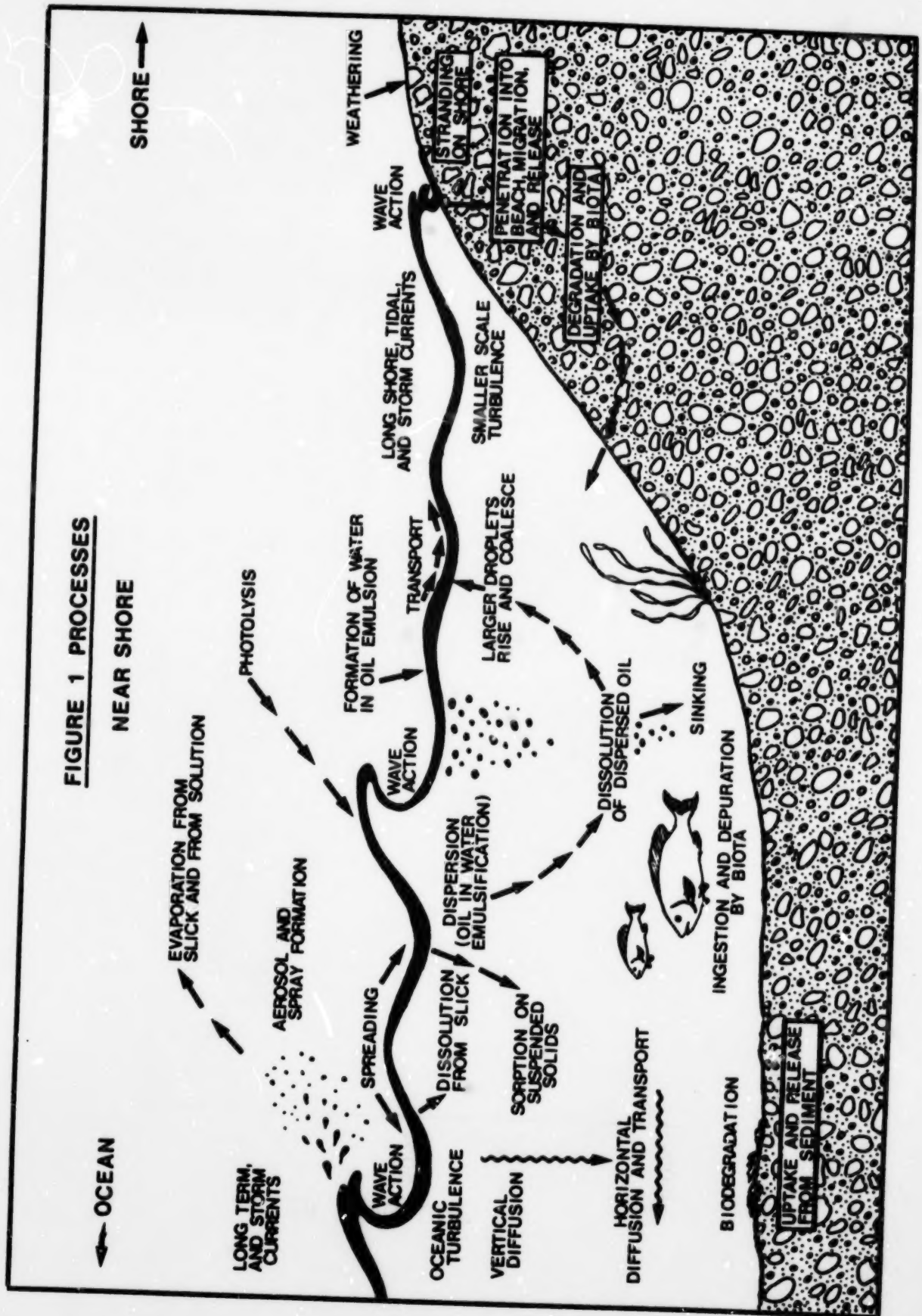
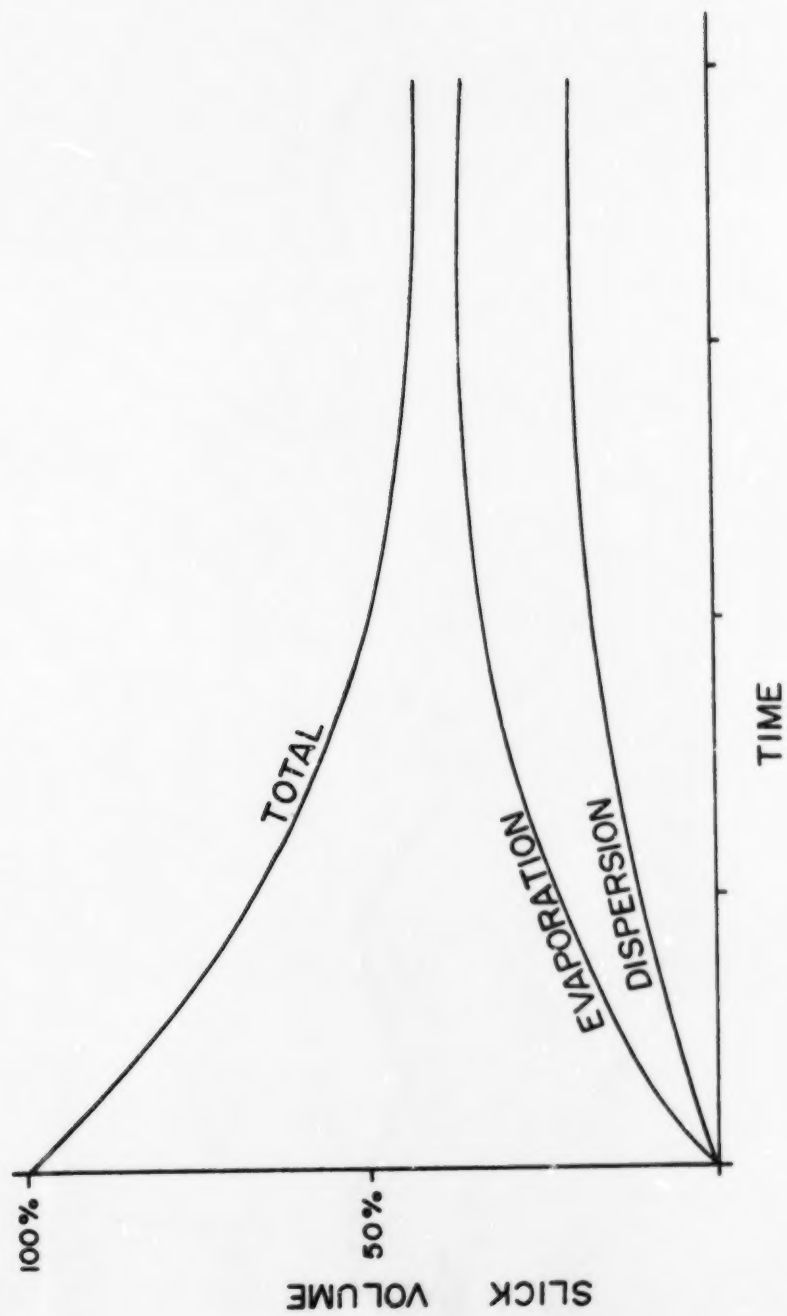


FIGURE 2 HYPOTHETICAL SLICK BEHAVIOUR



Evaporation models require, as input data, slick thickness, temperature, wind speed and temperature, and original oil composition. To test the model output, the determination of the change in oil composition with time is necessary.

Dispersion models require, as input data, slick thickness, wind speed, sea state, oil viscosity, oil-water interfacial tension, and water column density structure. Drop size is another important measurement, but there is no effective method for measuring the drop size in situ. To test the output of the models, measurements of slick area, oil composition and especially oil in the water column are necessary.

The data requirements are summarized in Figure 3.

1.3 Sampling Considerations

All of the selected processes are fast. It is necessary that the response to the spill be rapid and effective. The necessary sampling techniques should therefore be as simple as possible. Some data will be available from various sources after the fact, such as meteorologic data, but some measurements must be made to calibrate the data from distant stations.

An effective response will include both aerial and marine teams. Experience has shown that monitoring slick movement and shape is possible only with air support. A surface vessel has a very restricted visual capability, and must be directed from above.

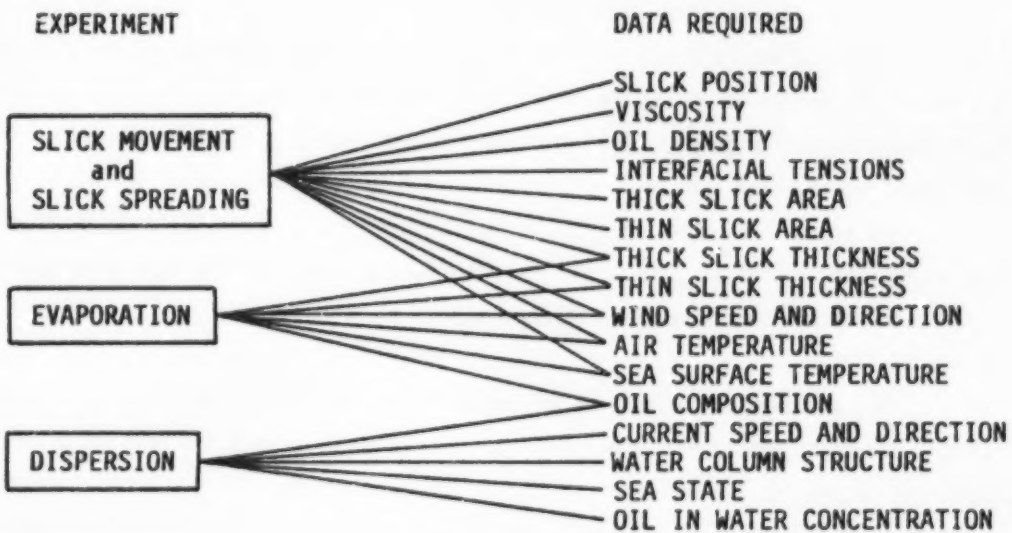
The air support would be responsible for directing the surface vessel to the slick. It would also be responsible for taking photographs of the slick at regular intervals, using good photogrammetric techniques so that proper measurements may be made. Part of the response kit must be an air photo log and instruction manual.

The surface vessel would have the responsibility of taking oil samples, accurately positioning the slick, measuring slick thickness, oil-in-water concentrations, water column structure, and taking meteorological data.

1.4 Spill Scenario

The major thrust of oil spill research in Canada in recent years has been directed to spills of crude oil, as the potential for a large spill during exploration, production, and transportation is high. Ideally, the response would be most useful in

FIGURE 3
DATA REQUIREMENTS



the case of such a crude oil spill. Historically, crude oil spills are unusual in Canadian waters, as there have been no major exploration or production accidents, and the transportation of crude oil does not occur in most areas of the coasts. There is a potential for transportation spills near the St. Lawrence River and in the Bay of Fundy on the east coast, and a lesser potential of the west coast, where heavy traffic occurs off-shore, from Alaska to the southern U.S.A., with some entry to the Strait of Juan de Fuca.

In most areas of Canada, the spills which have occurred, and are likely to occur, are spills of fuel products such as Bunker C or Number 6 fuel oil. Because such products are at the high boiling end of the distillation process, they are of higher viscosity and density than crude oils, and are less likely to evaporate or disperse than crude oil. Data obtained from such spills would not generally apply to the problem of crude oil behaviour.

The geographic areas in which a spill suitable for a rapid scientific response would have to occur are limited. Access to the spill would require an air facility and a source of suitable vessels. The spill would have to occur near a transportation center so that the equipment kits could be quickly brought to the scene, or occur near the base of the response team.

Three areas in Canada are appropriate locations for response. The Strait of Juan de Fuca, the Beaufort Sea, and the entrance to the St. Lawrence River are potential spill areas, are close to transportation centers, and have scientific groups actively involved in oil spill research nearby. The placement of rapid response kits at local government research facilities or with local consulting companies would be possible. In all three areas, air support and vessel support are possible.

Because of the time required to mobilize a response team, even if it is well prepared, a suitable spill will have to be large or continuous. A small spill would be hard to find after a day, and the processes we propose to study would be near their final stages. A large spill would have a slower time scale due to the bulk of the oil. A field response of two days will probably cover the most significant events, as it is the early data which applies to the problems being addressed.

The weather conditions at the time of the accidental spill will be critical to the potential for collecting useful data. Severe conditions of temperature or wind would make a response difficult.

A decision table for determining a response is shown in Figure 4. The final decision would be subjective, but the elements in the table are those which are most important.

**FIGURE 4
DECISION TABLE**

SPILL REPORT

1. Is the spill in a responsible area?
Yes: go to question 2
No: monitor the spill progress, no response at this time.
2. Is the spill large?
Yes: initiate mobilization.
No: go to question 3.
3. Is the oil a crude or a light fuel?
Yes: go to question 4.
No: monitor the spill progress, no response at this time.
4. Will there be fresh oil when we arrive?
Yes: initiate mobilization.
No: monitor the spill progress, no response at this time.

2. METHODOLOGY

The response is directed to three areas; slick movement and spreading, evaporation, and dispersion. As seen in Figure 3, much of the data is required to address more than one of these areas. This section will be organized according to the area of interest in which a method first appears.

2.1 Slick Movement and Spreading

2.1.1 Response in the Air

Aerial reconnaissance is absolutely essential to the success of a scientific response to a spill of opportunity. It can often be impossible to see the slick from the sea surface although it is visible from the air. The spotter in the air must direct the surface vessel to appropriate locations in the slick so that suitable samples may be taken.

In addition to directing the surface vessel, the spotter will be responsible for taking useful air photographs. Ideally, vertical photographs are most useful. If the lens focal length and the altitude of the aircraft are recorded, measurements may be made of slick dimensions. As the deviation from vertical increases, the usefulness of the photograph decreases, until a natural horizon is included in the photograph, when measurements are again possible. Under most coastal circumstances, a natural horizon is not likely to appear, except when the spill occurs on an open coast and the photographs are taken looking seaward. Every attempt should be made to take vertical photographs. A careful log must be kept if the photographs are to be of use. If possible, the photograph should include an identifiable object on the sea surface, such as the sampling vessel or a hula hoop or drogue, so that the photographic measurements may be associated with surface measurements.

A suitable camera for this task should include a short focal length lens, a bulk film back, and if possible, an internal date and time sequencer. Nikon can supply such a system.

2.1.2 Response on the Surface

The surface vessel will be responsible for positioning the slick, collecting meteorological and physical oceanographic data, and collecting slick samples for later analysis.

2.1.2.1 Positioning

In order to monitor slick movement and spreading, it will be necessary to position various parts of the slick regularly. A dedicated positioning system, such as a Mini-Ranger, would be ideal but would be expensive and require time and effort to set up. It is more likely that a navigation system and/or a radar would be available on board the surface vessel, and good positions may be obtained from these. In an open area, a Loran C unit will provide adequate positioning data. A log of Loran C numbers, including channel number, can be converted later to lat-long or UTM positions. Many nearshore areas, such as the Strait of Juan de Fuca and the Strait of Georgia are now being calibrated for Loran C. If the spill is in a relatively enclosed area, it is possible that radar fixes may be taken. If this is the case, regular photographs of the radar screen image, identified to time and scale, are very useful for more careful plotting of positions back in the laboratory.

2.1.2.2 Tracking

The deployment of a number of surface tracking devices, such as the radio tracked Orion buoys, or the much cheaper hula hoops, will help coordinate the air and surface measurements. If possible these devices should be individually identifiable from the air.

2.1.2.3 Sampling

Samples of the oil should be taken at regular intervals, starting as early in the spill as possible. If a sample can be obtained of unspilled oil from the source of the spill, it should be taken. These samples will be used for viscosity, density, and compositional analysis later. The samples may be taken with a sample bottle on a

rod, sealed, wrapped in a labelled baggie, and wrapped in another baggie for storage. The samples should be kept cold (frozen, if possible) and out of direct light. The position of the sample when taken, and the time, are essential data.

2.1.2.4 Slick Thickness

The thickness of the slick should be measured on a regular basis in a variety of positions within the slick. The Ross-Belore sampler should be used (Figure 6).

2.1.2.5 Meteorology and Physical Oceanography

The surface vessel must maintain a regular log of air temperature, relative humidity, wind speed and direction, surface water temperature, and surface current. Equipment for this function would include wet and dry bulb thermometers, surface thermometer, anemometer (hand held), compass, and profiling current meter. Except for the latter, no large investment is required and the items should be permanently part of the kit. The profiling current meter will be one of a number of costly items that will not be permanently part of the kit, but will be available on a loan or lease basis at short notice. These measurements will be done just outside of the slick, so that the instrument does not pass through the slick.

2.2 Evaporation

2.2.1 Response from the air

No participation is anticipated by the spotter aircraft for this part of the experiment.

2.2.2 Response on the Surface

The data and samples collected by the surface vessel for the spreading experiment are sufficient for the evaporation part of the response.

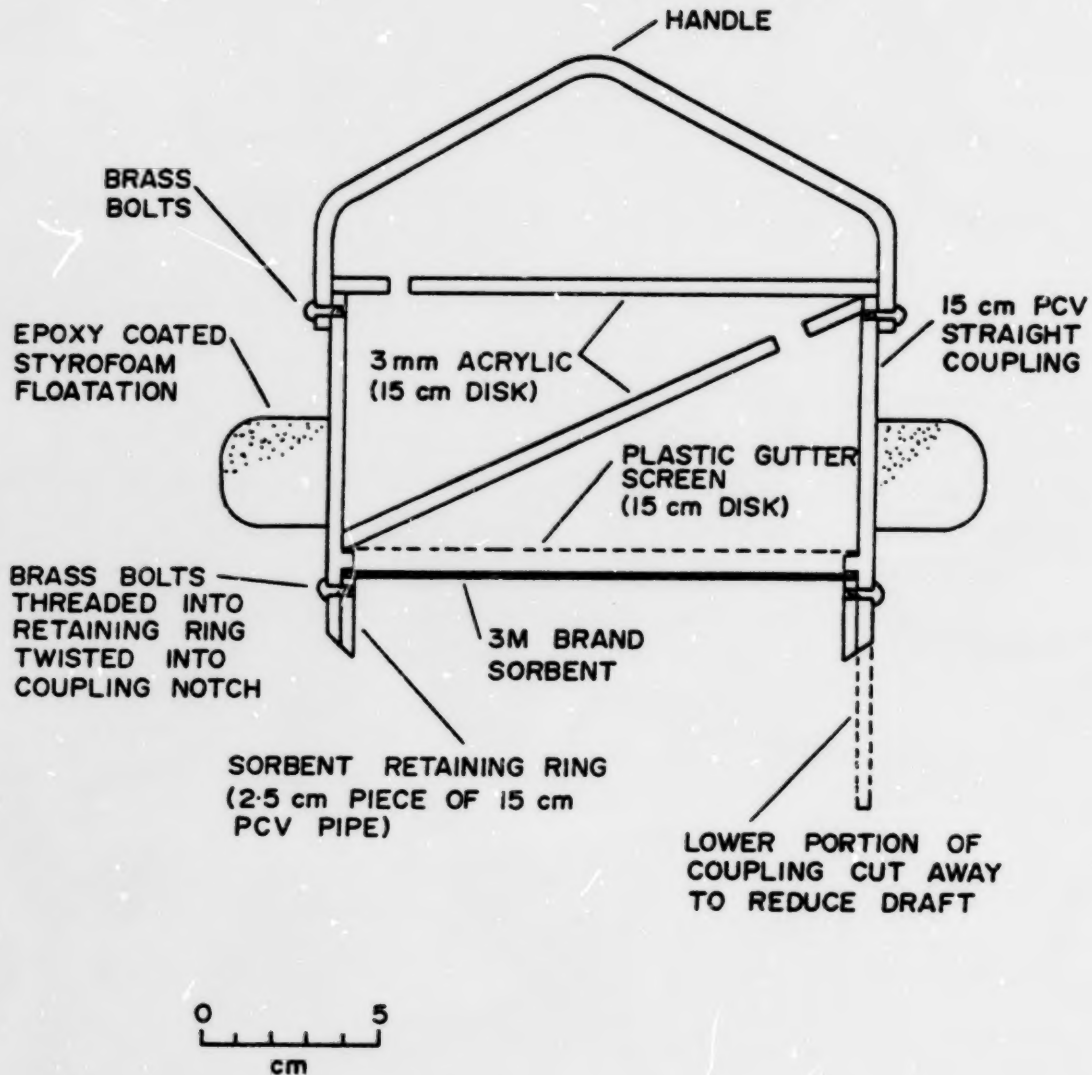


FIGURE 5 ROSS/BELORE SAMPLER
(BELORE, 1982)

2.3 Dispersion

2.3.1 Response from the Air

The spotter aircraft will have the responsibility of guiding the surface vessel during its monitoring program. Particular attention will be directed to the photographing of the drogues deployed by the surface vessel.

2.3.2 Response on the Surface

2.3.2.1 Water Column Characteristics

In addition to the data and samples described in Section 2.1.1, the surface vessel will regularly monitor the water column using a CTD (Conductivity, temperature, depth). This instrument will not be included permanently in the kit, but will be available on a loan or lease basis. These casts will be done just outside the slick, to avoid passing the instrument through the slick.

2.3.2.2 Tracking Dispersed Oil

It is known that surface slicks and associated dispersed oil do not necessarily move together, as wind and wave effects may operate more strongly on the surface slick. In order to follow water masses near the surface, 0 to 2 m window shade drogues, with radar reflectors, will be deployed at regular intervals. The spotter aircraft will assist the surface vessel in following these drogues.

2.3.2.3 Monitoring Dispersed Oil in the Water Column

It is necessary to monitor the concentration of dispersed oil under the slick and perhaps in the water column remote from the slick. Three levels of effort are available to do this. The lowest level will consist of a submersible pump and a large number of sampling bottles. The pump will be placed in the water well outside of the slick, and the vessel moved into the slick while the pump is working. Samples will be taken at various depths, locations, and times to delineate the concentration and extent of dispersed oil. This method is not interactive, as the samples cannot be analysed on board the vessel, and provides only point/time data.

The next level of effort will be to attach a Turner Designs fluorimeter to the output of the pump, calibrated for crude oil. Using a data logger or strip chart recorder, the concentration of dispersed oil may be monitored continuously. A record of position is added to the chart at regular intervals. Samples will be taken as before for calibration of the instrument to field conditions. This method will provide a large amount of data to be analysed after the field program.

Both methods described above require that the vessel move slowly from position to position inside the slick, to keep the pump well submerged at all times. Experience shows that the best technique is to move the vessel slowly with the pump far enough under to avoid contact with the surface oil, stop the vessel and do a down profile and an up profile, then move on. Experience has also shown that devices to allow faster travel, such as booms, cause more trouble than can be justified. Calibration samples should be taken whenever high concentrations of dispersed oil are found, and details of position, depth, and time recorded.

The third level of effort which solves the problem of speed and therefore extends the coverage is the use of a towable submersible fluorimeter. Such an instrument is available through the Environmental Emergency Branch, and will be available to spill response teams. This instrument is towed at various depths under the slick, and can cover a large area in a short time. This also increases the amount of data to be handled after the field work. In an ideal response to a suitable spill, all three levels of effort should be used. The three efforts should complement each other, in that calibration samples should be taken at positions, depths, and times when corresponding data is available from the other two methods. Care must be taken to collect data consistently. The surface markers and especially the drogues should be used as position identifiers. It is more useful to take samples and measurements at fewer positions more often than to cover many positions once only.

2.4 Sampling

Three types of oil samples will be collected. The 3-M absorbent pad from the thickness sampler, oil slick samples, and dispersed oil samples.

2.4.1 Cleaning of Containers

The containers for the slick thickness samples and the dispersed oil samples must be hydrocarbon clean. The glass containers are washed carefully, rinsed with methylene chloride, and baked overnight at 350 C. The containers then have a few milligrams mercuric chloride added and are closed with Al foil. Teflon liners for the closures are cleaned by Soxhlet extraction with methylene chloride.

2.4.2 Slick Thickness Samples

The absorbent pad from the sampler is removed and placed in a hydrocarbon cleaned (see section 2.4.1) 8 ounce glass jar. If possible the sample is frozen until analysis. If immediate freezing is not possible, the sample should be kept cool in the dark until freezing can occur.

The sample is extracted for analysis by placing 300 mL of solvent (depending on the analytical method) in the jar and shaking on a paint shaker for 5 minutes. The method of analysis will depend on the laboratory available, but will probably be one of visible spectrophotometry, UV spectrophotometry, UV fluorescence spectrometry, or infra-red spectrophotometry. Regular calibration samples (10-15%) based on original oil must be included in the analytical protocol.

2.4.3 Slick Compositional Samples

The samples obtained for compositional analysis do not need to be collected into hydrocarbon cleaned containers, but the containers should be cleaned by washing. The samples should be placed in a clean 40 dram vial, the vial closed, placed in a labelled baggie (Whirlpak is ideal), and the labelled bag placed in another bag for storage. Again, freezing should occur as soon as possible. The sample should be kept cool and away from light until frozen.

To prepare subsamples for the various analyses, the vial is carefully rinsed with methylene chloride to remove any oil from the outside. Subsamples may then be taken for GC analysis of the composition, density, viscosity, and surface tension. Details of analytical methods will again depend on the laboratory involved, but should always be standard or accepted methods.

2.4.4 Dispersed Oil Samples

The dispersed oil samples will be collected in hydrocarbon cleaned and poisoned beer bottles. The bottles are filled only to the shoulder, a teflon liner placed over the mouth, and the bottle capped. The bottles should be kept cool and out of direct light until analysis.

The bottles are opened in the laboratory, solvent added, and the bottle shaken on a paint shaker for 5 minutes. The solvent is withdrawn, dried, and analysed by an appropriate method. Fluorescence analysis is probably the most useful. As it is a non-destructive method, samples of interest may be further analysed by GC to monitor compositional changes. Again, details of the methods will depend on the laboratory.

2.5 Support Requirements

A response to an oil spill of opportunity will be successful only if good support is available. It is essential that one aircraft and at least one surface vessel be exclusively available to the response team.

2.5.1 Air Support

This component of the response effort is probably the most expensive and most essential. Either a helicopter or a light fixed wing aircraft is suitable. It will not be necessary that the aircraft is in constant surveillance of the slick, although that would be ideal. It is necessary that regular overflights be made. A removable door is useful for taking vertical photographs. Communication with the surface vessel will be possible with a hand held marine VHF kept with the response kit.

2.5.2 Surface Support

Most areas in which a response to a spill will be made have active fishing industries or exploration activities. Both can be sources for vessels of opportunity for the response. The vessel(s) selected must be large enough to comfortably carry three or four persons and their associated equipment. A fishing vessel 30' or larger, with some clear deck space, would be suitable. On the east coast, 30-40' Cape

Islanders are common. On the west coast, combination troller/gillnetters, or larger seiners, are common. In the Beaufort, the choice is more limited, but there is significant oil industry activity which may provide vessels. In some areas, research vessels may be available. These would be better as the crews are usually more familiar with the type of work required.

The vessel should be equipped with marine VHF, depth sounder, radar and Loran. Almost all fishing vessels in the size range considered have these instruments. Lifting gear is not essential.

If more than one vessel is available and there is enough money to pay for it, the activities may be divided. One vessel should handle the slow moving activities, such as monitoring the dispersed oil with the pump, while the other vessel monitors the slick dimensions and tows the submersible fluorimeter. If only one vessel is available, the scientist in charge will have to be careful in deciding upon the level of effort to be attempted by that vessel. It is very easy in these circumstances to try to collect more data, to the detriment of the results. The plan as it stands increases in complexity and decreases in probable success with each additional experiment.

3. EQUIPMENT

3.1 Fast Response Kit

The kit(s) should be prepared immediately and held by a trained group ready to mobilize at any time. The kit should contain the following equipment, packaged in a form allowing easy handling and shipping.

AIRCRAFT PACKAGE

- Instruction manuals
- Log books
- Air maps of the response area
- Camera with data back and bulk load
- Film; preferably Ektachrome, ASA 100
- Dark bag; for film loading in the field
- Marine radio; VHF multi-channel hand held

SURFACE PACKAGE

- Instruction manuals
- Log books
- Anemometer (hand held)
- Compass
- Sextant
- Charts for response area
- Camera; Polaroid or equivalent
- Film for above
- Thermometers
 - Air temperature, wet and dry
 - Sea surface
- Hula hoops
- Drogues; 0-2m, window shade

Surface slick samplers

Slick thickness samplers

Slick thickness sample containers

Slick composition samplers

Slick composition sample containers

Submersible pumps, with tubing for 15m

Plumbing to attach fluorimeter (see below)

Dispersed oil sample containers

Salinity bottles

3.2 Level 2 Equipment

In addition to the basic kit, which will allow a significant fast response, some additional expensive equipment should be included for more complete monitoring of the dispersed oil. This equipment should be identified by the response team and arrangements made for its use in case of a spill. Such equipment could be available from local institutions or consulting companies, and borrowed or rented for the response only. The response kits above should include manuals for these items, and shipping containers if they are not normally included.

Profiling current meter

CTD

Turner Designs Flow-through Fluorimeter

Oil kit for above fluorimeter

Recorder for fluorimeter

3.3 Level 3 Equipment

If time and location allow, the submersible fluorimeter assembly developed by the Environmental Emergency Branch of E.P.S. should be used to track dispersed oil. This unit consists of a submarine with a fluorimeter inside, a towing cable and towing davit, and deck data logging equipment. This equipment comes as a package ready for loading on a small vessel (Sealander or commercial fish boat) and could be used independently of the surface sampling vessel, with direction from the spotter aircraft.

4. CONDUCT OF THE PROJECT

The direction of the response will have to be made at the time of the spill when conditions are known. The following comments are for general direction only.

4.1 Preparation and Management

The first part of the response is the preparation of the fast response kit and the organization of the response team, including some training.

An evaluation of the response area must be made. An analysis of previous spills and an evaluation of the ability to respond are necessary for decision making. The availability of air and surface support, transportation to the area, and so on must be identified and listed, so that an early decision may be made. Charts and maps of the appropriate areas should be obtained for inclusion in the kits, and annotated with relevant information. Some assistance may be available in this planning from the Coast Guard Emergency Planning groups in the area.

The basic kits must be prepared. The equipment must be obtained and instruction guides pertinent to this project prepared. Log books which will include all the necessary data will be made up. These will include aircraft logs, photographic logs, sample logs and weather logs. It is essential that these logs be made up ahead, as the stress of responding to a spill will induce some forgetfulness in the field. Good log books will remind workers of the required data collections.

Some of the equipment in the kits is available commercially, while other items, such as the thickness sampler, must be fabricated. Details of the equipment are found in Appendix A1. A critical requirement is the provision of containers for the kits that will provide secure storage for the gear, and be easily transported at the time of response. It is essential that the basic kit be kept intact. The loss of the camera from the air package, for example, would seriously affect the quality of the photographic record when a "camera of opportunity" was used without the data recording capability or the most suitable lens.

The planning team will locate the appropriate extra equipment and make arrangements for its use at short notice.

4.2 Mobilization

The preparation stage will have identified information routes so that the response team will be notified quickly, and have identified transportation routes so that the team can arrive on scene with as little lost time as possible.

As soon as notice is given, a decision to respond must be made. If the planning has been adequate, this should not be difficult. Before departure, arrangements for air and surface support will be made. Any of the extra equipment which is available will be collected and prepared for transport.

4.3 Field Program

Upon arrival on the scene, the senior scientist will begin the aerial surveying of the spill. The senior technician, with assistance from two junior technicians, will load the surface vessel and set up to begin sampling while the surface vessel is underway to the spill site, as directed from the air.

The first priority of the surface team is to obtain a sample of the freshest possible oil. If this is obtainable from the source, this is ideal. Alternatively, a sample should be obtained from the central area of a spill, where the oil is thickest. After this, the Hula hoops and drogues should be deployed as directed by the air spotter and regular sampling should begin. The protocol for this will depend on the level of effort being expended. If only a Level 1 effort is possible, then regular surface samples and thickness samples will be taken. Meteorological data will be recorded on a regular basis; half-hourly if possible. Positions should be recorded as often as possible. If the vessel is moving continuously, a position and time must be recorded for each data point or sample taken. If the vessel is stationary much of the time, positions should be taken half-hourly.

The amount of work to be done on each experiment should be carefully considered. The first experiment, the movement and spreading of the slick, is easiest to do and stands the greatest chance of success. The second, evaporation, is taken care of in the sampling and data collection of the first. A decision to attempt the third, at any level, should be made only if the effort expended will not detract from the first two. Care must be taken not to spread the effort so thin that none of the experiments are successful.

For the first two experiments, the sampling should cover both thick and thin slick areas, and have a reasonable time sequence for repeat sampling. The senior scientist must direct the surface vessel in such a way as to cover a reasonable number of locations many times.

For the dispersion experiment, at a Level 1 or 2 effort, the sampling should be restricted to only a few locations in the slick, perhaps two in the thick area and one in the thin area, and these locations should be sampled from the surface to 5 or 10 m depth a number of times. If the submersible fluorimeter is available, then a regular transit between the three locations used at Level 1 and 2 should be made at varying depths down to 5 or 10 m. Again, the decision of where to locate the sampling sites will be best made when some data is available, such as the submersible fluorimeter finding a lens of oil at a certain depth at a particular location. This should then become one of the regularly sampled sites.

4.4 Report

After the field response is complete, the samples and data must be logged and organized. Some chemical analyses will be done, the number depending on the number of samples taken and the rate of change of the properties observed. An analytical scheme which selects the minimum number of samples to identify changes should be used.

The data should be organized to provide a description of the spatial and temporal changes in the slick position, shape, and thickness and the changes in composition of the various types of oil in the slick. At this stage, no attempt to fit the data to a particular model should be made; the goal is to empirically describe the behaviour of the spilled oil.

The type of data presentation that will be most useful will likely have the following formats:

Environmental data

- time series plots of
 - wind speed and direction
 - air temperature
 - sea temperature
 - current speed and direction

Slick movement

- plots of slick center, hula-hoops, and drogues with time

Slick spreading

- plots of slick shape with time
- graphs of slick area with time for thick and thin slicks
- plots of slick thickness with time and location
- graphs of oil properties with time
- estimated oil budgets

Evaporation

- graphs of percent loss of volatiles with time for thick and thin samples

Dispersion

- plots of concentration of dispersed oil by location, depth and time
- dispersed oil budget, by depth and time to evaluate resurfacing and dissolution

The synthesis of the data produced by a fast response to a spill of opportunity will depend on the quantity and quality of the data collected. The use of the data to evaluate and modify models will most likely be done by the proponents of the various models.

5. PERSONNEL REQUIREMENTS

In order to provide an effective response within a small budget, a team of four field workers is necessary. The preparations should be directed by the senior scientist for the response, who will also lead the field team. He will be assisted in the preparations by a senior technician, and in the field by the same technician and two junior technicians. Both the senior scientist and the senior technician should have considerable experience in oil spill research, as it will be necessary to make many ad hoc decisions throughout the response. All personnel should have backups in case of non-availability, and the team and backups should all be trained in the use of the equipment.

6 . **REFERENCES**

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APPENDIX A. EQUIPMENT

AIRCRAFT PACKAGE

Air maps of the response area: after a decision is made regarding a reasonable response area, the appropriate air maps should be obtained, in case the chartered craft does not have them.

Camera with data back and bulk load: Nikon makes a camera, the F3, which will accept a bulk load data back and motor drive (MF17). While this item may seem expensive, its use can save many hours later when photographs are being logged.

Film; preferably Ektachrome, ASA 100. Slides can be projected to any size, so that scales may be adjusted more easily.

Dark bag; for film loading in the field. Although the bulk data back holds 250 frames, it may be necessary to reload in flight; also, a stuck film can be repaired in flight.

Marine radio; VHF multi-channel hand held. Numerous models are now available, with up to 68 channels.

SURFACE PACKAGE

Anemometer (hand held). Available in yacht supply outlets.

Compass. A prism hand held compass will be useful in positioning.

Sextant. Useful for taking horizontal angles. Davis makes a useful sextant for about \$50.00. Also available in yacht supply outlets.

Camera; Polaroid or equivalent. If radar is being used, or if some close views of the slick are required, a very high speed camera is useful. The details of the photograph can be written on a label and attached immediately.

Film for above. Very high speed is best for pictures of radar images. B&W is best. Colour will be necessary for pictures of slick.

Thermometers

Air temperature, wet and dry
Sea surface

Hula hoops. These can be made from commercial hula hoops covered with a bright nylon cloth, with a 15 cm hole in the center. Some bright identification mark, such as fluorescent cloth cut as different shapes will aid identification even if oil gets on the top surface.

Drogues; 0-2m, window shade. See Figure 5. The drogue consists of a pole with a radar reflector, identified by a unique colour pattern, with a float and a window shade drogue attached. The window shade is a polypropylene tarp with a flotation member at the top and a weighted member at the bottom. The drogue pole is attached at the bottom of the window shade.

Surface slick samplers

Slick thickness samplers. The Belore/Ross sampler (Belore, 1982) is described fully in the reference.

Slick thickness sample containers. At least 50 3M pads cut to shape and 50 hydrocarbon clean jars to accomodate the pad are required.

Slick composition samplers. These samplers may consist of poles with holders for small (40mL) vials at the end.

Slick composition sample containers. At least 100 40 mL vials.

Submersible pumps, with tubing for 15m. Little Giant pumps are readily available in a variety of sizes. The only requirement is that a 1/2" pipe thread fitting is on the outlet. Polyethylene tubing (1/2") with polyethylene fittings complete the unit.

Plumbing to attach fluorimeter. Inlet and outlet tubes, light tight for at least 1m, and with fittings to attach to the pump outlet tubing. Samples may be taken from the outlet of the fluorimeter.

Dispersed oil sample containers. Hydrocarbon clean beer bottles (one shape only), with a teflon cap liner, regular beer cap, and a capper. At least 100.

Salinity bottles. Standard salinity bottles. 25.

Profiling current meter. A number of types are available. For this use, any device with a deck readout in real values of current speed, direction and depth would be useful.

CTD. Again, a number of types available. A data logger built in will defer the effort of calculating values until later.

Turner Designs Flow-through Fluorimeter. The Model 10-005 Field Fluorimeter is ideal, although bench and rack models can be used with care. A general calibration before going to the field, for some convenient crude oil, is useful. For most uses without calibration, setting the instrument to its most sensitive will be best.

Oil kit for above fluorimeter. Most crudes likely to be encountered, and most light fuels, respond to the short wavelenght kit. Heavy fuels (Bunker C and No. 6 Fuel Oil) will respond to long wavelengths. Both would be a good idea.

Recorder for fluorimeter. A simple and cheap Houston Omniscribe in a good field box is best.